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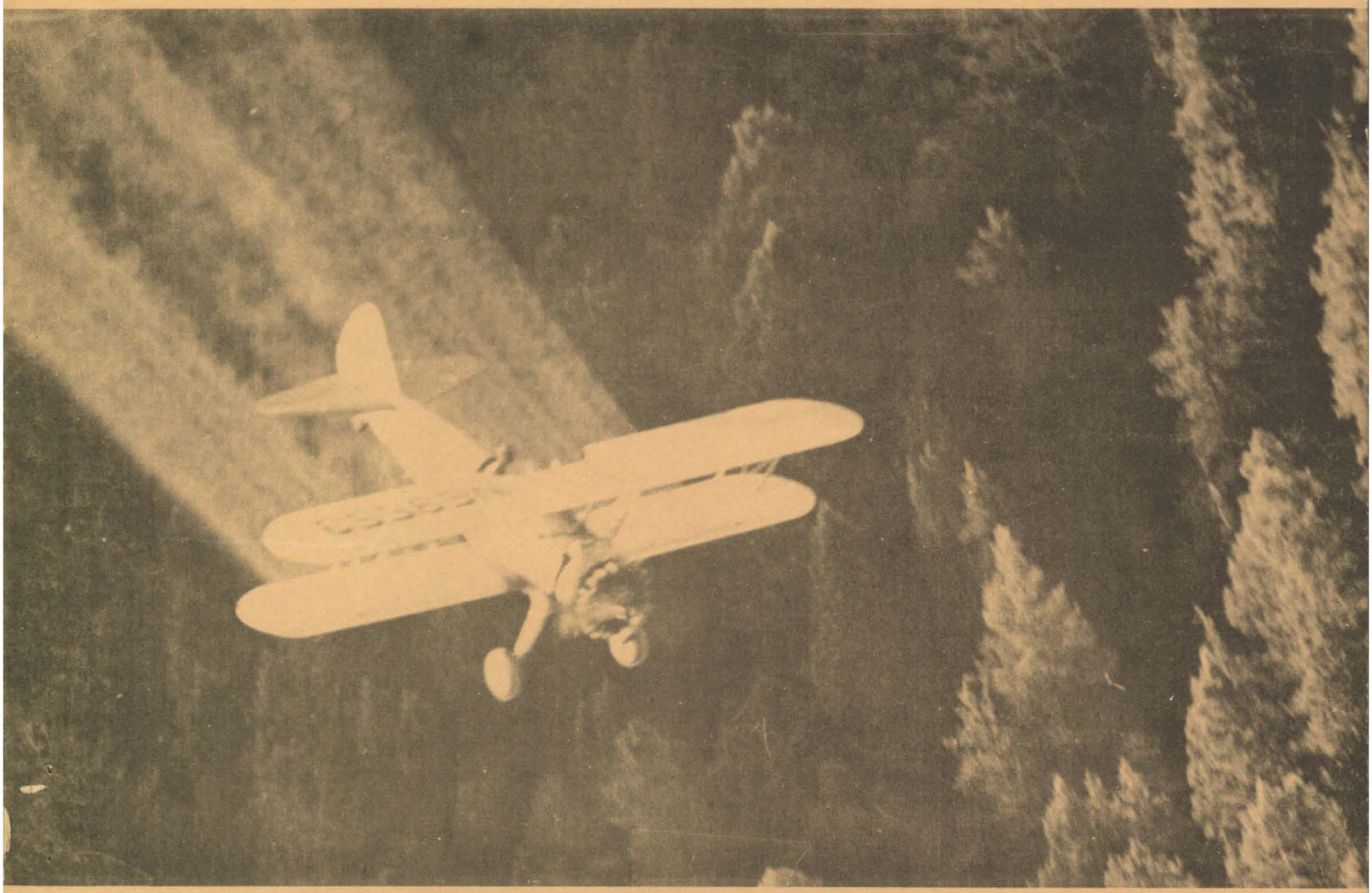
ENTOMOLOGICAL PHASES OF THE 1955 MONTANA SPRUCE BUDWORM CONTROL PROJECT.



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REPORT OF THE ENTOMOLOGICAL PHASES OF THE 1955 MONTANA SPRUCE BUDWORM CONTROL PROJECT

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SUMMARY

The 1955 spruce budworm control project undertaken by the Forest Service in Montana is herein reported. The operational phases were administered by the Division of Timber Management, Region 1, with the cooperation of other Federal forest and park agencies, the Montana State Board of Forestry, and private timberland owners. The entomological phases were administered by the Missoula Forest Insect Laboratory of the Intermountain Forest and Range Experiment Station.

The Gardiner control unit of the project comprised 77,444 acres of the Gallatin National Forest and 55,412 acres in Yellowstone National Park, part of which was in Wyoming. The project's second unit covered 169,087 acres in the Bitterroot National Forest. A third unit of 70,709 acres in the Nezperce National Forest, Idaho was treated concurrently, but administered as a part of a separate project embracing budworm infestations on the Boise and Payette National Forests and contiguous lands in southern Idaho.

The technical services provided the Montana project included (1) determining the extent and severity of epidemic budworm infestations from combined aerial and ground budworm appraisal surveys and from the forced emergence of overwintering budworm larval populations, (2) determining the need for control from an entomological standpoint, (3) recommending the method of control, (4) timing the control treatment, and (5) checking the adequacy of the treatment.

Spraying operations on the Gardiner Unit began July 5 and were terminated July 20. Spraying on the Bitterroot Unit was done between July 19 and 30. All acreage scheduled for spraying was treated in both units before budworm brood development had progressed beyond the point where further spraying would have been ineffective.

Spray deposition was measured as one factor in determining the adequacy of the control treatment. Droplet size and the amount of spray reaching the ground, in gallons per acre, were assessed from oil-sensitive dye cards placed in many of the spray blocks of each unit. Supplemental evidence of spray evidence was obtained from foliage spotting caused by the oil in the insecticide, aerial observation of the spray planes at work, the observance of postspray larval threads, initial larval mortality, and the detection of insecticide odor following spraying. All spray deposition was approved.

The project's effectiveness was further measured by sampling to determine budworm mortality. The budworm mortality obtained on the Gardiner and Bitterroot control units was 90.9 and 93.5 percent, respectively.

Some improvements in technical services are suggested covering the fields of training, better prediction of budworm larval development rate, and new concepts of assessing control effectiveness.

ENTOMOLOGICAL PHASES OF THE 1955 MONTANA SPRUCE BUDWORM CONTROL PROJECT

INTRODUCTION

A total of 372,652 acres of Douglas-fir and true fir forests were treated by the U. S. Forest Service in July 1955 by the aerial application of DDT insecticide to control parts of epidemic infestations of the spruce budworm, Choristoneura fumiferana Clem., in northern Idaho and western Montana. Of this amount, 70,709 acres were treated on the Salmon River District of the Nezperce National Forest, Idaho. This latter operation was administered as part of a similar control project on the Boise and Payette National Forests in southwestern Idaho carried out by the Ogden, Utah regional office of the Forest Service (Region 4). Technical services on the Salmon River project were provided by the Boise Research Center of the Intermountain Forest and Range Experiment Station.

The remaining treated acreage was divided between two control units; the Gardiner Unit, 132,856 acres, (fig. 1) of which 77,444 acres are in the Gallatin National Forest, Montana, and 55,412 acres in Yellowstone National Park, Montana and Wyoming, and the Bitterroot Unit, (fig. 1A) consisting of 169,087 acres in the Bitterroot National Forest, Montana.

Treatment of the Montana areas was under the over-all supervision of the Missoula regional office (Region 1) of the Forest Service with the cooperation, as in Region 4, of State and other Federal forest agencies and private timberland owners.

Technical services were provided for the Montana project by the Missoula Forest Insect Laboratory of the Intermountain Station. These services included (1) determining the extent and severity of epidemic budworm infestations from combined aerial and ground budworm appraisal surveys and from the forced emergence of overwintering budworm larval populations, (2) determining the need for control from an entomological standpoint, (3) recommending the method of control, (4) timing the control treatment, and (5) checking the adequacy of the treatment.

Detailed procedures for the complex biological measurements needed for the precise timing of the control treatment and for checking its adequacy were outlined in a guideline[1/] prepared by the Intermountain Station.

The organization chart in the appendix, table A, illustrates the personnel relationships and responsibilities.

1/ Johnson, Philip C. Plans for the technical direction of the 1955 spruce budworm control project in western Montana and northern Idaho. Unpublished report of the Missoula Forest Insect Laboratory, Intermountain Forest and Range Expt. Sta., Forest Service, Ogden, Utah. May 1, 1955. /Processed./

PRECONTROL APPRAISAL SURVEYS

Aerial and followup ground surveys in 1954 delineated 2,184,390 acres of current epidemic spruce budworm infestations in western Montana, the northern part of Yellowstone National Park, Wyoming and Montana, and in northern Idaho. Defoliation from 1954 budworm feeding varied from light to heavy in the host timber types, principally true fir (Abies sp.) and Rocky Mountain Douglas-fir (Pseudotsuga menziesii var. glauca /Beissn./ Franco) in northern Idaho and this variety of Douglas-fir almost exclusively in Montana and Yellowstone Park. From the above acreage predominantly Federal-owned blocks of budworm-infested forests were selected for control in 1955.

Budworm population density in the proposed 1955 control units was checked by the Missoula Forest Insect Laboratory in March and April 1955 by forcing the emergence of overwintering budworm larvae from bole sections of infested fir trees. Results of this rearing (table 1) indicated that populations were heavy enough to warrant control in 1955.

Table 1.--Precontrol spruce budworm larvae populations from bole sections collected from control areas

Control unit	Drainage	Bole bark surface (sq. ft.)	Number of larvae	Average number of larvae per sq. ft.
Gardiner[1/]	Cinnabar	14.1	1,819	129
	Mol Heron	5.6	397	71
	Bear Creek	6.6	78	12
	Trail Creek	5.9	301	51
	Cedar Creek	4.6	95	21
	Stevens Creek	4.9	37	8
	Undine Falls	4.7	249	53
	Oxbow Creek	4.2	248	59
	Tower Falls	4.8	650	135
		55.4	3,874	70
Bitterroot	Chicken Creek	6.9	487	71
	Hughes Creek	5.6	399	71
	Cameron Creek	5.9	35	6
	Lyman Creek	5.8	242	42
	Meadow Creek	4.9	17	3
	Jennings Camp[2/]	5.6	62	11
	East Fork Station	4.5	114	25
		39.2	1,356	35

1/ Stevens Creek, Undine Falls, Oxbow Creek, Tower Falls units are in Yellowstone National Park, remaining Gardiner Unit drainages are in the Gallatin National Forest.

2/ Sprayed in 1952.

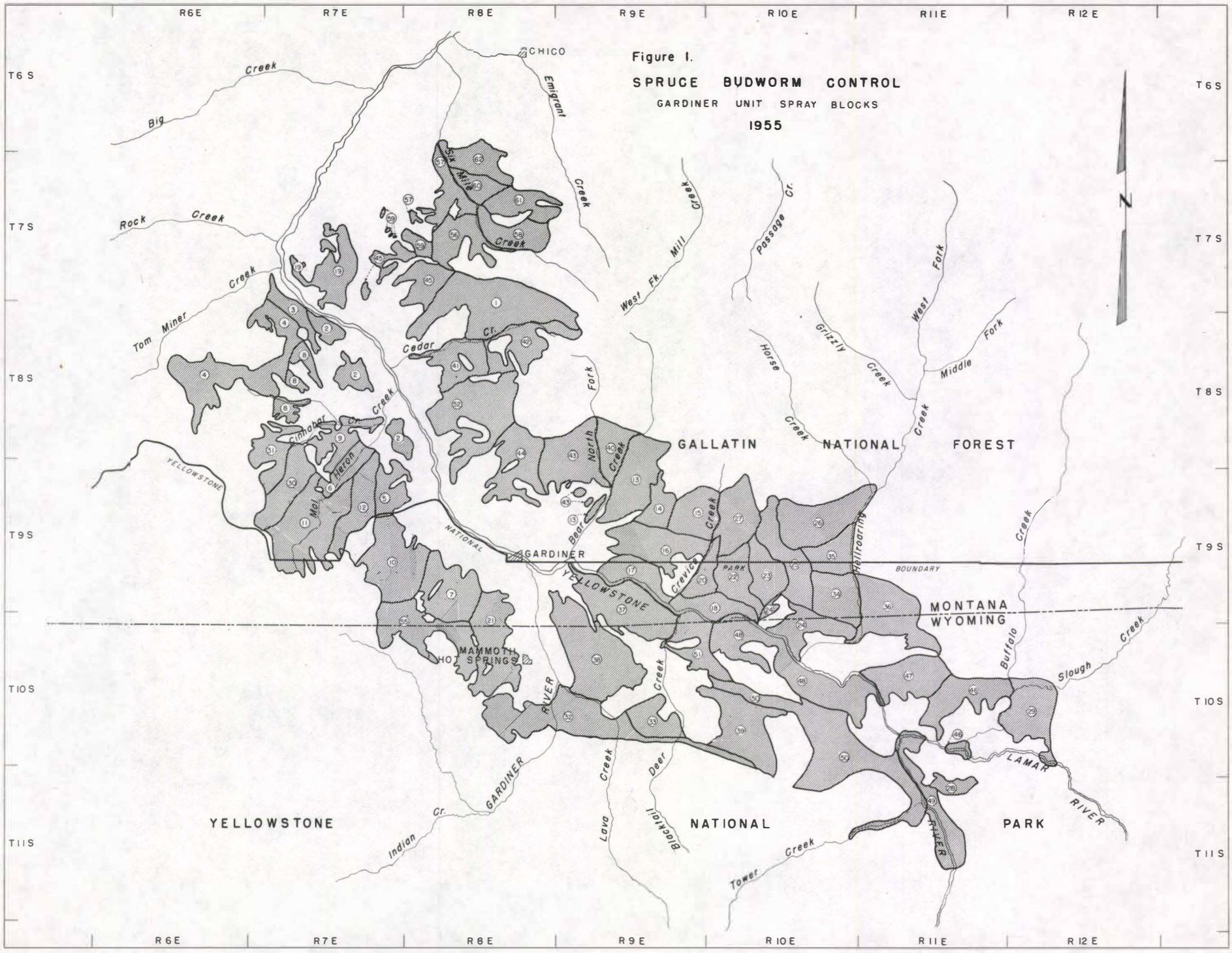


Figure 1.
SPRUCE BUDWORM CONTROL
GARDINER UNIT SPRAY BLOCKS
1955
R6E
R7E
R8E
R9E
R10E
R11E
R12E
T6S
T7S
T8S
T9S
T10S
T11S
N
CHICO
Big Creek
Rock Creek
Tom Miner Creek
Cinnabar Cr.
Mol Heron Creek
Six Mile Creek
Emigrant Creek
West Fk. Mill Creek
Cedar Cr.
Fork
Passage Cr.
Horse Creek
Grizzly Creek
West Fork
Middle Fork
Creek
North Bear Creek
Crevice Creek
Hellroaring Creek
Creek
GALLATIN NATIONAL FOREST
YELLOWSTONE
NATIONAL PARK
BOUNDARY
MONTANA
WYOMING
GARDINER
MAMMOTH HOT SPRINGS
YELLOWSTONE RIVER
Indian Cr.
GARDINER RIVER
Lava Creek
Deer Creek
Blacktail
Tower Creek
Buffalo Slough Creek
LAMAR RIVER

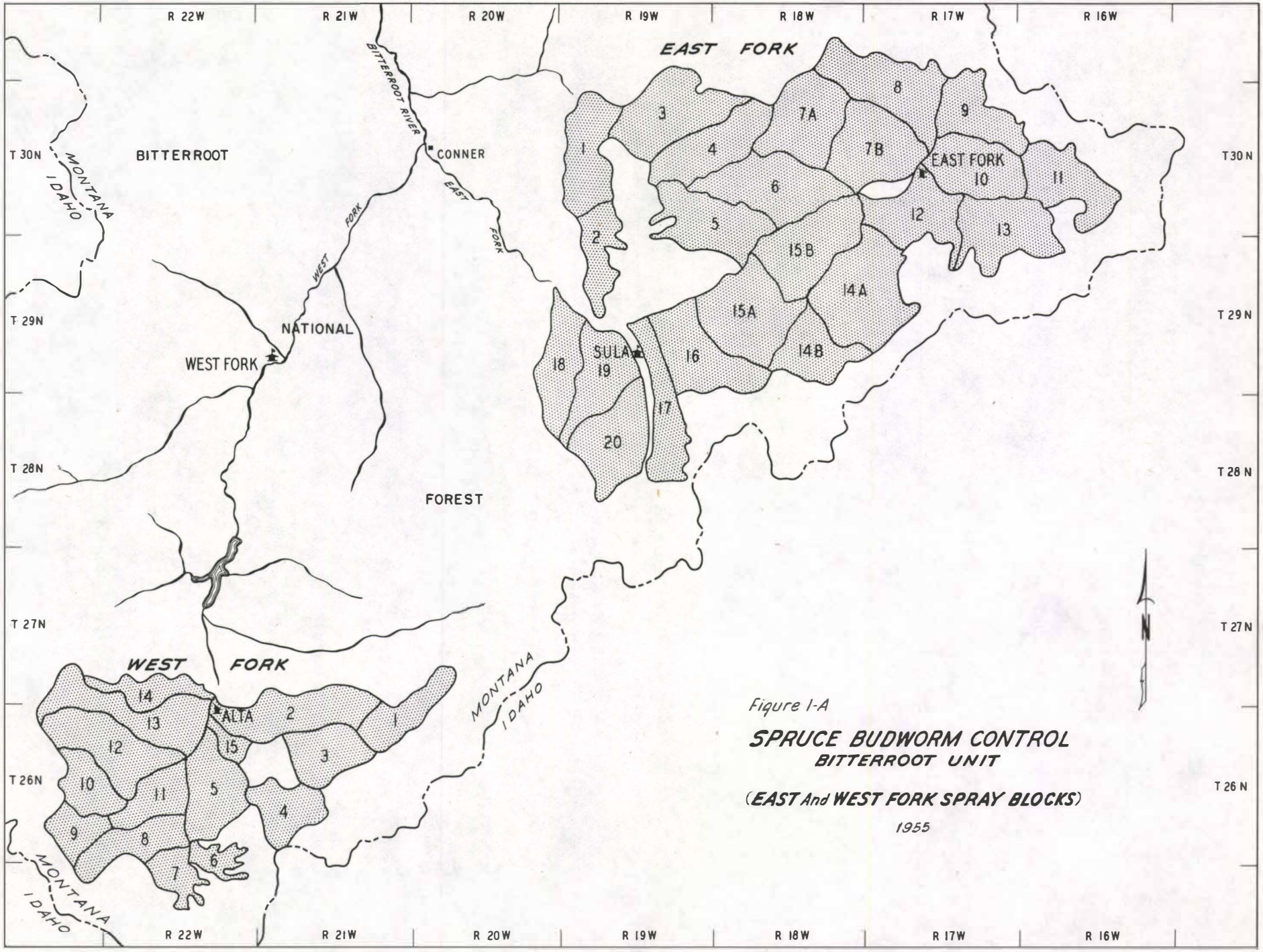


Figure 1-A

SPRUCE BUDWORM CONTROL
BITTERROOT UNIT

(EAST And WEST FORK SPRAY BLOCKS)

1955

During May and June the Laboratory assisted national forest personnel in establishing the precise boundaries of the two Montana control units by means of operational surveys. These were designed to locate areas of very light infestation contiguous to but beyond the limit of the infested areas defined by the appraisal survey. They also separated infested host type from noninfested host type or nonhost type within the control unit.

RECOMMENDED CONTROL METHOD

The control method recommended by the Intermountain Station and used by the 1955 project was a standardized technique used since 1948 for controlling spruce budworm epidemics in the western United States. It consists, in general, of the aerial application of DDT insecticide to the infested forests.

Its many requirements, however, make it one of the most exacting of all forest pest control operations.

Insecticide

The insecticide formulation used on the project was as follows:

DDT, technically pure	1 pound
Auxiliary hydrocarbon solvent	1.25 quarts
#2 fuel oil, to make	1 gallon at 60° F.

The insecticide contractor formulated the above mixture at Missoula, Montana for the Montana control units only and supplied samples for compliance testing by the Agricultural Research Service insecticide laboratory at Yakima, Washington. All lots of mixed insecticide delivered by the contractor to the project met the required formulation specifications.

Insecticide Application

The formulated insecticide was applied over the infested forests from contracted fixed-wing aircraft under the following conditions:

Dosage per acre.--One gallon in spray form.

Droplet size.--Mass median diameter; average 150 microns, maximum 300 microns, minimum 50 microns.

Height of release.--From 200 to 400 feet above the upper canopy surface of the infested forest.

Climate.--No spraying during rainstorms, preferably from 1 hour preceding and for period following storm necessary to dry foliage. Wind not to exceed 6 miles per hour in any direction. Air temperature in spraying area not to exceed 68° F. These climatic limitations required most of the spraying to be done between the hours of 4:00 a.m. and 10:00 a.m.

TIMING THE CONTROL TREATMENT

Control treatment--aerial spraying--began in each spray block in each control unit when 50 percent of the budworm population was made up of 5th and 6th instar larvae. Spraying was terminated, if still in progress, when 5 percent of the budworm population had advanced to the pupal stage. This was determined by daily larval collections from established sampling points in the spray blocks. The unit biologist (see Organization Chart, appendix table A) determined the location of these points and assigned them to insect checkers for larval collections. Procedures followed those outlined in the plans for the technical direction of the project except for some minor modifications in the Gardiner Unit. In general, daily collections of budworm larvae and foliage development observations were made by the insect checkers at each sampling point when the larvae reached the 3rd instar. The larvae in each daily sample were classified by instars by the unit biologist using ocular comparisons with known instar standards or larval head capsule measurements. In this way the rate of larval development could be plotted and a prediction could be made of the probable date that 50 percent of the budworm population would reach the 5th and 6th instars, assuming normal seasonal climatic conditions continued to prevail.

Larval development permitted the beginning of spraying operations in the Gardiner Unit on July 5 at elevations below 8,000 feet. The budworm population above this elevation was treated beginning July 8. Spraying continued daily except for occasional interruptions because of adverse climatic factors. It was terminated on July 20 when all acreage scheduled for treatment had been adequately sprayed and before the percentage of budworm population in the pupal stage in all but one block had exceeded 5 percent. Pupae in parts of Block 60, Lower Six Mile Creek, suddenly increased to as much as 25 percent of the population on July 20, the last day of spraying in the Unit.

Weather conditions played an important role in the timing of spraying operations in the Bitterroot Unit. The weather was unseasonably cold and wet in early July, with frost on July 2 and rain on 12 of the first 14 days of that month. The rains resulted in cooler air temperatures and consequent delay in budworm development.

Most of the budworm larvae in the Bitterroot Unit remained in the 2nd instar until June 20 when a few 3rd instar larvae were observed. Daily larval collections by the insect checkers began on June 22. The majority of the larvae remained in the 3rd and 4th instars until July 14. The period July 15 to 18 was one of unseasonably warm air temperatures and larval growth advanced with sudden rapidity. Fifth and sixth instar larvae averaged 50 percent of the budworm populations in several low elevation spray blocks on July 19 and spraying in these blocks was begun on that date.

Favorable spraying weather and rapid larval development contributed to the early release of all spray blocks and by July 22 most of the spray blocks were ready for spraying.

On July 23 a meeting of entomological, operational, and contractor personnel was held at Hamilton, Montana to discuss the necessity of increasing daily spraying capacity because of an unexpected speeding up of budworm development. Information furnished by the unit biologist indicated that pupae would exceed 5 percent of the budworm population on or about July 29. Inasmuch as the contractor's spray planes were considered by the project supervisor to be of inadequate tank capacity to complete spraying of the entire unit by that date, 30,000 acres of the unit were withdrawn from the primary contractor and awarded on July 23 to a secondary flying contractor. Spraying was completed on all but about 5,000 acres of the unit on July 29 and special clearance was given by the project technical director to complete spraying of the latter acreage on July 30.

ADEQUACY OF THE CONTROL TREATMENT

Spray Deposition

Approximately 132,800 acres were sprayed in the Gardiner Unit. This acreage was divided into 60 spray blocks varying in size from 850 to 4,000 acres and in elevation from 5,000 to 9,000 feet. The terrain was extremely rough and steep in many of the blocks. The 169,087-acre Bitterroot Unit was divided into 37 spray blocks with similar area variation from 850 to 7,200 acres and with ground elevations ranging from 4,000 to 8,000 feet above sea level. The terrain was steep but not as rough as that in the Gardiner Unit.

As a rule a single spray plane worked in one block. A few blocks were finished in a single day, most required 3 or 4 days spraying and the longest period was 9 days. Because the terrain was so steep in some instances it was virtually impossible for the pilot to cover the block progressively finishing a block at a time. In such cases steep side hills were flown three and four times to get the required gallonage on them.

Spray deposit determination was undertaken on the basis of checking each block. Methods of checking spray application were (1) use of dye cards to show the spray deposit, (2) examining deciduous foliage for oil burn, (3) examining the block for mortality to the insects, and (4) aerial observation of the spraying.

Dye cards.--Cards 4 x 5 inches in size coated with an oil-sensitive dye were placed in many of the blocks before they were sprayed and retrieved after the spray was applied. The cards were placed on lines at 5-chain intervals with 10 cards constituting a card line. Each card was placed in the open on a relatively flat spot and held down by a single nail pressed through its center. A total of 64 card lines were placed in 37 blocks in the Gardiner Unit and 95 lines in 34 blocks in the Bitterroot Unit. These were successfully retrieved.

Other card lines were set out but in some instances the interval between the placing of the cards and the spraying was so long as to make the cards useless. In other instances some card lines were left when it was found that a disproportionate number of card lines fell in some of the blocks. This occurred because the cards were laid out before the area was subdivided into blocks.

From the collected dye cards an approximation of the spray gallonage per acre reaching the ground was obtained by comparing them with calibrated spray deposit standards. The cards indicated average deposits varying from 0.04 to 0.76 gallon per acre.

Considerable difficulty was experienced with the use of dye-sensitive cards. Sunlight bleached them badly and rain showers affected the dye. Cards damp from dew apparently did not register drop size well and in many instances cards curled into a cylindrical shape after being laid out. The cards proved attractive to rodents which chewed the edges of some and to larger mammals which chewed the entire card and to birds (probably ravens) which are believed to have taken many of the cards. Approximately 7 cards out of each line of 10 were retrieved.

Obviously, the ideal system would be to lay the cards out just prior to spraying and pick them up immediately after spraying. However, because of the difficult terrain in much of the Gardiner Unit, the cards at best had to be laid out the day prior to the start of spraying and left for several days until spraying was completed in that particular block. In one group of four blocks, a 3-day horseback trip was required to lay out cards and was later repeated to collect them.

In some instances spraying activities were shifted during the morning's work period from blocks where cards had been laid to blocks where no cards had been laid. These shifts of work areas came about because of the vagaries of the weather. Wind and sometimes morning fog prevented the spraying of blocks as previously planned while acceptable weather existed in other blocks. The alternative was to cease work for the day or spray in the available blocks. Permission to change work areas was always requested in such instances and it was always granted. However, this often nullified prearranged dye card placement and results.

Foliage spotting.--Droplets of the spray mixture containing DDT, a solvent, and oil caused oil-burn spots to form on most broadleafed plants. Various kinds of plants reacted differently under the same quantity of spray. Some plants having a heavy pubescence such as black currant were quite resistant to oil-burn. On plants having a waxy leaf coating, the oil droplets spread over the surface. Apparently, the most sensitive plants were wild strawberry and rose. These two plants were almost universally distributed throughout the control units and the spray droplets produced a marked oil-burn spot on the leaves that was very close to the size of the spots produced on the dye cards.

Oil-burn spots on foliage became an important means of checking spray deposit because various parts of blocks not sampled by dye cards could be examined. Collections of oil-burned leaves were made in conjunction with the collection of dye cards, and these were often collected in other parts of the spray blocks, as a supplement to dye cards. Where no dye cards were used ground checks of oil-burned foliage became the primary means of determining the extent of the spray deposit.

Aerial observation.--Aerial observation of the spraying provided additional information on the application of spray. While it was used only to supplement various ground checks it is believed to have been one of the most important means of determining the thoroughness of the spraying pattern. Also, aerial observation was the only means by which spray plane heights above the timber could be readily judged.

The pattern of spray droplets forming the characteristic foggy mist behind the spray plane is influenced by ground winds, thermal air movement, and air temperature. These factors often disrupt the spray by causing it to drift to one side or the other, or worse, to simply hang in the air or even rise. Aerial observation is the only practical means by which this action of the spray can be effectively observed.

While no decision to respray was ever made from aerial observation alone such observations did indicate where lightly sprayed areas might be found. Subsequent ground check usually substantiated the observations and in some instances, additional spray was applied.

Other methods.--Methods of spray deposit determination other than the aforesaid dye-cards, foliage spot, and aerial observation were used on both control units. These were the presence of dead spruce budworm larvae and the presence of larval threads from larvae dropping out of the sprayed trees. To be of value as evidence of spray, dead larvae and larval threads must be observed soon after spraying. Within a few days wind and rain eradicate much of this evidence.

Insecticide odor and ground observation of spraying were not often used as checks of spray deposit.

Spray deposit approval.--Approval by the unit biologists of the spray deposit in each of the blocks was based upon the following:

1. An average minimum spray deposit from the dye cards of 0.20 gallon per acre.

2. Assurance from the unit supervisor that the total amount of insecticide used in the block, in gallons, equalled 0.8 the net sprayable area of the block, in acres.

3. Acceptable evidence of spray deposition other than from dye cards.

Approval of the spray deposit in each block was made after completion of spraying in the block and as soon as spray deposit evidence could be collected and analyzed. Approval was given from 1 to 12 days with an average of 3 days.

Postspray Budworm Mortality

One or two days before spraying, previously located budworm mortality lines were installed by the insect checkers under the supervision of their respective unit biologists. These lines ran at right angles to the proposed lines of flight in blocks released for spraying.

Ten sampling stations were used on each mortality line, the stations being established at 5-chain (330-foot) intervals if on paced lines, or 0.2 mile apart if the line was contiguous to a road.

Two 15-inch branches were clipped from each of 5 infested trees at each sampling station. All living budworm larvae and pupae were counted and placed in alcohol for possible future reference.

Seven to 10 days after spraying the same lines were rerun and the same procedures followed except that surviving budworm larvae and pupae were counted from four 15-inch branches from each of the 5 infested trees at each sampling station. All collected budworms were placed in alcohol for further reference.

The percentage of mortality was computed by the following formula:

$$\text{Percent mortality} = \frac{\overline{(\text{Prespray count} \times 2) - \text{Postspray count}} \times 100}{\text{Prespray count} \times 2}$$

The computed percentage of budworm mortality in the Gardiner Unit was 90.9 and in the Bitterroot Unit, 93.5 (table 2). It ranged from 58.0 to 99.5 percent in individual spray blocks in the Gardiner Unit and from 80.3 to 100.0 percent in the Bitterroot Unit (appendix tables B and C)

The effectiveness of the control effort, in terms of budworm mortality, may be gaged by the following accepted standards:2/

Excellent control	(98-100%):	Project average should fall in this range.
Good control	(95-97%):	Acceptable for blocks and occasional units.
Marginal control	(90-94%):	Acceptable for occasional blocks but not for units.
Poor control	(Below 90%):	Unsatisfactory; respraying probably necessary.

The above mortality percentages do not reflect the effectiveness of natural control factors which may have been operative at the time of, or subsequent to, spraying. Budworm parasites at this time may account for additional mortality to surviving larvae or pupae. No information is available as to the amount which may have occurred on this project, but other projects in the Western United States have had budworm mortality percentages computed from spraying boosted from 1 to 2 percent for entire control units.2/

Table 2.--Budworm mortality, 1955 Montana spruce budworm control project

Control Unit	Number of blocks	Blocks sampled		Number of mortality lines	Number of sampling stations	Average mortality percentage
		Number	Percentage			
Gardiner	60	18	30.0	29	290	90.9
Bitterroot	38	36	94.7	55	550	93.5

1956 Defoliation

A further measure of the adequacy of the 1955 control project in Montana is indicated by the amount of budworm defoliation in the control units and adjacent check areas during 1956. Defoliation sampling was carried out in the Gardiner and Bitterroot Units in August 1956 using a procedure employed in budworm appraisal surveys elsewhere in Montana and northern Idaho in 1956.3/ The procedure is not aimed at determining the actual amount of needle loss, but at estimating the percentage of 1955 and 1956 internode foliage showing evidence of budworm feeding.

2/ Whiteside, J. M., Wessela, C. P., and Compton, L. M. Report of the 1955 Oregon spruce budworm control project. Report of the Pacific Northwest Forest and Range Expt. Sta., Forest Service, Portland, Oregon. April 1, 1956. /Processed./

3/ McComb, David. Spruce budworm ground appraisal survey procedures. Unpublished report of the Missoula Forest Insect Laboratory, Intermountain Forest and Range Expt. Sta., Forest Service, Ogden, Utah. July 1956. /Processed/

The comparison of defoliation in table 3 indicates that 1956 defoliation in the Gardiner control unit is one-third that in the adjacent check area with comparable infestation conditions. A direct control vs. check comparison is not possible in the Bitterroot Unit inasmuch as the 1955 control treatment encompassed all known budworm infestation, some of which was accompanied by heavy defoliation. The Bitterroot check areas contained relatively new budworm infestation with exceedingly light defoliation. The 1955 control treatment in the Bitterroot Unit did succeed, however, in reducing defoliation in the unit by 51.3 percent, and the resultant amount of 1956 defoliation was nearly equal to that resulting from the concurrent control treatment in the Gardiner Unit.

Table 3.--Comparison of 1956 defoliation in 1955 controlled and uncontrolled spruce budworm infestation areas in Montana

Unit	1955 treatment	Percentage of defoliation 1/	
		1955	1956
Gardiner	control	not available	26.5
	check	81.4	78.1
Bitterroot	control	49.4	24.1
	check	31.6	26.5

1/ Expressed as the percentage of 1955 and 1956 internode foliage showing evidence of budworm feeding; not as total needle loss.

SUGGESTED IMPROVEMENTS IN TECHNICAL SERVICES

Training

Spruce budworm control projects in Montana in 1952, 1953, and 1955 were each staffed by different technical personnel which was either temporarily detailed to the project from other functional assignments or employed for its duration. Because of the intermittency, the relative short project life, and the variability of insect control work, the Station maintains no personnel permanently assigned to carry out the entomological phases of each control project. The constant change of the technical personnel on successive budworm control projects has made job training a recurring task. Despite more and more standardization in job techniques, training for the jobs continues to vary between projects according to the individual effort of the supervisory technical personnel responsible for training.

Continuity in the technical details between Forest Service-sponsored projects can be assured by well-conceived training programs employing recognized training aids and the advice and assistance of the regional training officer. Such planned programs will facilitate the training of personnel detailed or employed for budworm projects, particularly when much of the training must be done by technicians who themselves are detailed to the project. The programs should result in better trained project personnel and consistently higher quality technical services.

Better Prediction of Budworm Larval Development Rate

Several sequences in every budworm control program are geared very closely to budworm larval growth or development. Better means of detecting the ending of hibernation in the field would assist in closer scheduling of seasonal employment or the detailing of technical personnel to the control project. The breaking of hibernation was a phenomenon only casually observed in the 1955 project and, as a result, it was not until posthibernation larval development had proceeded for some time that any firm prediction could be made of the date on which the project's technical staff should be on the job.

Better prediction of the rate of larval development between the 3rd and 6th instars is needed, too, to assure project operational personnel more opportunity to marshal supplies, manpower, and control equipment in time for the beginning of control treatment. Factors such as cumulative hour-degrees of air temperature should be studied for their effect on the larval development rate and then some practical method needs to be devised for their field measurement. The difference of only one day in scheduling the start or ending of aerial spraying on a large budworm control project could mean the difference of many thousands of dollars in total project cost and it could seriously influence the control effectiveness of the entire project. These, in themselves, are sufficient justification for such a study.

Concepts of Assessing Control Effectiveness

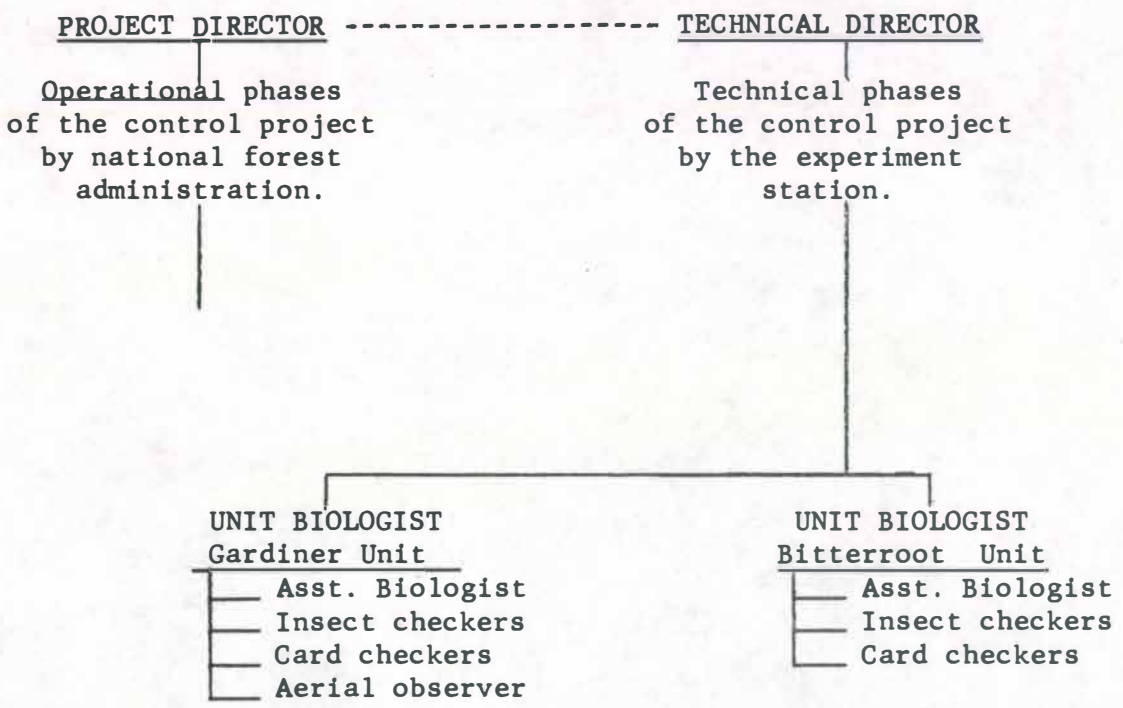
The traditional measure of budworm control effectiveness is the percentage of the prespray larval population killed by the insecticide (see page 9, this report). Mortality percentage alone cannot adequately express the effectiveness of spraying, for, unless 100 percent kill is obtained, a residual larval population will remain which may or may not become the nucleus of reinfestation depending upon its subjugation to natural control factors. The magnitude of this residual population will vary, not alone with the percentage of kill achieved by the aerial spraying, but with the degree of predation, parasitism, or disease infection of the residual population and, equally important, with the magnitude of the prespray larval population.

Larval mortality percentages now considered unacceptable may actually yield a smaller residual population in a control block or unit than an acceptable percentage in an adjoining unit if the prespray population of the former was light and that of the latter area very dense.

Much remains to be known of the reinfestation potential of residual budworm populations of various degrees of density, but it seems reasonable even now to assume that this factor should be an element in the assessment of budworm control effectiveness.

A P P E N D I X

Appendix table A.--Technical organization chart, 1955 Montana spruce budworm control project



Appendix table B.--Budworm mortality, Gardiner Unit, 1955
Montana spruce budworm control project

Block number	Number of lines	Percentage of mortality	
		By individual mortality lines	Block average
1	1	97.0	97.0
2	1	99.4	99.4
4	2	96.9, 88.7	92.8
21	2	94.7, 69.0	81.9
32	2	98.7, 85.5	92.1
36	1	97.0	97.0
38	2	96.0, 94.0	95.0
40	1	99.5	99.5
41	4	100.0, 98.8, 98.6, 96.7	98.5
42	2	88.5, 80.0	84.3
48	1	97.8	97.8
49	1	97.7	97.7
50	3	94.0, 93.6, 93.0	93.5
52	2	98.5, 97.4	98.0
57	1	98.3	98.3
58	1	58.0	58.0
60	1	61.0	61.0
62	1	93.9	93.9
		Average for unit	90.9

Appendix table C.--Budworm mortality, Bitterroot Unit, 1955 Montana spruce budworm control project

Block number	Number of lines	Percentage of mortality	
		By individual mortality lines	Block average
		EAST FORK	
1	2	97.8, 97.9	97.9
2	1	98.9	98.9
3	2	96.4, 97.3	96.9
4	2	98.4, 98.2	98.3
5	1	86.4	86.4
6	1	97.7	97.7
7a	1	100.0	100.0
7b	2	98.7, 100.0	99.9
8	2	94.8, 85.3	90.1
9	3	94.4, 84.2, 89.0	89.2
10	2	98.3, 98.3	98.3
11	2	88.7, 77.8	83.2
12	1	80.3	80.3
13	2	91.7, 96.4	94.1
14a	2	78.2, 91.1	84.7
14b	2	100.0, 98.8	99.4
15a	2	86.7, 87.5	87.1
15b	1	98.3	98.3
16	2	95.8, 93.0	94.4
17	2	94.3, 98.6	97.0
18	1	98.4	98.4
19	1	98.5	98.5
20	1	100.0	100.0
		Average for subunit	94.3

Continued

Block number	Number of lines	Percentage of mortality: By individual mortality lines	Percentage of mortality: Block average
		WEST FORK	
1	1	85.1	85.1
2	2	97.6, 70.8	84.2
3	1	90.9	90.9
4	1	91.9	91.9
5	1	85.9	85.9
6	1	95.9	95.9
8	1	96.1	96.1
9	2	94.9, 92.4	93.7
10	1	97.3	97.3
11	1	98.4	98.4
12	1	99.3	99.3
13	2	96.0, 88.7	92.4
14	2	84.3, 90.0	87.2
		Average for subunit	92.2
		Average for unit	93.5